GEOLOGICA BELGICA (2000) 3/1-2 : 55-65

DINOFLAGELLATE CYSTS AND ACRITARCHS FROM THE MIOCENE ZONDERSCHOT SANDS, NORTHERN BELGIUM: STRATIGRAPHIC SIGNIFICANCE AND CORRELATION WITH CONTIGUOUS AREAS

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(4 figures, 1 table and 2 plates)

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ABSTRACT. A palynological investigation of the Miocene Zonderschot Sands (Berchem Formation) from the type locality Zonderschot (northern Belgium) has revealed the presence of a diverse dinoflagellate cyst and acritarch association. The dinoflagellates reflect a shallow marine environment, although the oceanic species *Nematosphaeropsis* and *Impagidinium* are prominent in the association and indicate the presence of an oceanic influence. This can be explained only by the depositional area being located at the very southern margin of the relatively isolated North Sea Basin during a period of maximum landward extent of the marine realm. A precise biostratigraphical correlation of the Zonderschot Sands with the Antwerpen Sands (Berchem Formation) from the Antwerp area is established. Biostratigraphical evaluation of key dinoflagellate cyst species indicates a latest Burdigalian (latest Early Miocene) - (earliest?) Langhian (early Middle Miocene) age for the Zonderschot Sands.

KEYWORDS: dinoflagellates, Zonderschot Sands, Miocene, North Sea Basin, Belgium

1. Introduction

The occurrence of the Miocene Zonderschot Sands (Huyghebaert & Nolf, 1979) in Belgium is restricted to the area southeast of Antwerp (Fig. 1). Deposition took place in a shallow marine environment along the southernmost border of the North Sea Basin. The Zonderschot Sands were first described from a temporary outcrop in the hamlet Zonderschot near Heist-op-den-Berg and informally defined by De Meuter (1974) and Ringelé (1974) in their unpublished PhD dissertations dealing respectively with Miocene benthic foraminiferal and molluscan associations from northern Belgium. De Meuter & Laga (1976, p. 135) described the Zonderschot Sands formally as "dark green, fairly fine, clayey, very glauconiferous sand; very rich in shells, homogeneously dispersed in the sediment, micaceous, concentrations of very coarse glauconitic grains, slightly ligniferous"; they incorporated the unit as a member in the upper part of their newly defined Berchem Formation (Fig. 2). Huyghebaert & Nolf (1979) redefined the Zonderschot Sands on the basis of observations in a boring at the type locality near the original outcrop, and observations from numerous new outcrops and borings in the vicinity. Huyghebaert & Nolf (1979) give a precise account of the areal distribution of the Zonderschot Sands. In the type-area, they

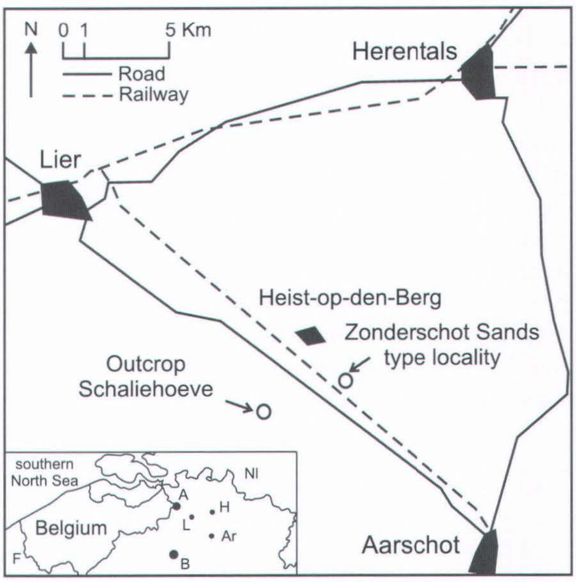

Figure 1. Location of the study area. Lambert co-ordinates of the type locality of the Zonderschot Sands (samples B237, B238, B239): x= 176.520; y= 194.600. Lambert co-ordinates of the outcrop Schaliehoeve (sample P5675): x= 173.170; y= 193.230. A: Antwerp, Ar: Aarschot, B: Brussels, H: Herentals, L: Lier, Nl: The Netherlands, F: France.

Lithostratigraphy	Series
Antwerp Campine area	
Diest Formation "Diest Sands" Dessel Sands	Upper Miocene
Berchem Formation Zonderschot Sands - Antwerpen Sands	Middle Miocene Lower Miocene

Figure 2. Lithostratigraphy of the Miocene in the Antwerp Campine area. Modified after De Meuter & Laga (1976).

rest unconformably on the Boom Clay Formation (Lower Oligocene), are overlain to the east and northeast by the Upper Miocene Diest Sands and wedge out to the south. These authors also describe a teleost otolith fauna characteristic of the Zonderschot Sands in a transitional area with a lithofacies resembling the Antwerpen Sands (medium- to coarse-grained, very glauconitic sand); this suggests a lateral equivalence of the Antwerpen Sands with the Zonderschot Sands, at least in the Heist-op-den-Berg area. These authors also give a historical overview of the earliest references in the literature of the Zonderschot Sands and its previously interpreted stratigraphic positions.

2. Biostratigraphy, age and radiometric data

Figure 3 gives an overview of the benthic and planktonic microfossils and otolith biozones identified in the Zonderschot Sands. The presence of calcareous nannofossil NN4 (Verbeek *&* *al.*, 1988) indicates a late Burdigalian to early Langhian age (Berggren *et al.*, 1995). The same samples as those studied here for the dinoflagellate cysts and taken from the original outcrop described by De Meuter (1974), were studied for planktonic foraminifera by Hooyberghs (1980). The latter author defines a local *Globigerinoides trilobus trilobus / Globigerinoides altiaperturus* Biozone to characterise the Zonderschot Sands. Additional observations by Hooyberghs (1996) have established the presence of Biozone N6 or Biozone N7 in the Zonderschot Sands, which would then indicate at least a Burdigalian age for the deposits. The age of the benthic foraminifera B7 Zone is Early Miocene (IGCP Working Group, 1988). The Zonderschot Sands are placed in the Middle Miocene *Uvigerina tenuipustulata - Elphidium inflatum* Zone (BFN2) by De Meuter & Laga (1976), Doppert *et al.* (1979) and De Meuter (1980). Teleost otoliths from the type-area of the Zonderschot Sands were studied in detail by Nolf (1977), Huyghebaert (1978) and, as already mentioned, by Huyghebaert & Nolf (1979). The otolith association points to a littoral-neritic fauna living in a rather warm and calm environment, without mechanical transport, during Middle Miocene times. Huyghebaert & Nolf (1979) estimate that the Zonderschot Sands were deposited in a shallower environment than the Antwerpen Sands. The association is furthermore characterised by excessively high numbers of *Gadiculus labiatus*, which distinguishes it from the Antwerpen Sands otolith association. Gaemers (1988) places the Zonderschot Sands in otolith Zone 12 (Oxlundian, late Hemmoorian). Until now, no biostratigraphical data from organic-walled phytoplankton have been available. Radiometric analysis using the K-Ar method on glauconites from the Zonderschot Sands revealed an apparent age of 15.1 ± 1.0 Ma (Odin *et al.*, 1974). This indicates a late Langhian - early Serravallian age, using the time scale of Berggren *et al.* (1995).

3. Material and methods

Four samples of the Zonderschot Sands were studied for dinoflagellate cysts. Three samples (nos. B237, B238, B239) are from the temporary outcrop in the type locality Zonderschot where the Zonderschot Sands were described and informally defined by De Meuter (1974) and Ringelé (1974). As previously noted, these

Microfossil group	Planktonic foraminifera	Benthic foraminifera		Calcareous nannoplankton	Gadidae otoliths
Biozonation / Member	Blow (1979)	IGCP 124 Working Group (1988)	Doppert *et al.* (1979) and De Meuter & Laga (1976)	Martini (1971)	Gaemers (1988)
Zonderschot Sands	N7 or N6	B7	BFN2 - *Uvigerina tenuipustulata - Elphium inflatum* Zone	NN4	Zone 12 *Colliolus mistensis* Zone
	Hooyberghs (1996)	Willems *et al.* (1988)	De Meuter & Laga (1976) Doppert *et al.* (1979) De Meuter (1980)	Verbeek *et al.* (1988)	Gaemers (1988)

Figure 3. Microplankton and otolith biozones recognised in the Zonderschot Sands.

Samples	P5675		B237	
Dinoflagellata				
	n	%	n	%
Apteodinium australiense (Deflandre & Cookson, 1955)	2	0,66	-	-
Apteodinium spiridoides Benedek, 1972	21	6,95	3	1,14
Apteodinium tectatum Piasecki, 1980	1	0,33	-	-
Batiacasphaera hirsuta Stover, 1977	-	-	-	-
Batiacasphaera minuta (Matsuoka, 1983)	1	0,33	-	-
Batiacasphaera sphaerica Stover, 1977	1	0,33	1	0,38
Cerebrocysta poulsenii de Verteuil & Norris, 1996	2	0,66	-	-
Cerebrocysta sp. cf. *C. satchelliae* de Verteuil & Norris, 1996	4	1,32	1	0,38
Cordosphaeridium minimum sensu Benedek & Sarjeant, 1981	-	-	3	1,14
Cousteaudinium aubryae de Verteuil & Norris, 1996	4	1,32	3	1,14
Cribroperidinium tenuitabulatum (Gerlach, 1961)*	1	0,33	-	-
Dapsilidinium pastielsii (Davey & Williams, 1966)	19	6,29	11	4,17
Dapsilidinium pseudocolligerum (Stover, 1977)	-	-	1	0,38
Dinocyst sp.7 Manum *et al* . 1989	-	-	4	1,52
Distatodinium paradoxum (Brosius, 1963)	1	0,33	5	1,89
Filisphaera microornata (Head *et al* ., 1989)	1	0,33	-	-
Filisphaera cf. *microornata* (Head *et al* ., 1989)	2	0,66	2	0,76
Hystrichokolpoma rigaudiae Deflandre & Cookson, 1955	4	1,32	1	0,38
Hystrichosphaeropsis obscura Habib, 1972	2	0,66	2	0,76
Impagidinium paradoxum (Wall, 1976)	-	-	4	1,52
Invertocysta lacrymosa Edwards, 1984	-	-	1	0,38
Labyrinthodinium truncatum modicum de Verteuil & Norris, 1996	5	1,66	11	4,17
Lejeunecysta spp. indet.	-	-	2	0,76
Lingulodinium machaerophorum (Deflandre & Cookson, 1955) subsp. *machaerophorum*	9	2,98	6	2,27
?*Lingulodinium multivirgatum* de Verteuil & Norris, 1996	2	0,66	-	-
Melitasphaeridium choanophorum (Deflandre & Cookson, 1955) subsp. *choanophorum*	16	5,30	6	2,27
Microdinium reticulatum Vozzhennikova, 1967	1	0,33	-	-
Nematosphaeropsis labyrinthus (Ostenfeld, 1903)	-	-	4	1,52
Operculodinium centrocarpum (Deflandre & Cookson, 1955) subsp. *centrocarpum*	20	6,62	15	5,68
Operculodinium longispinigerum Matsuoka, 1983	-	-	-	-
Operculodinium piaseckii Strauss & Lund, 1992	2	0,66	-	-
?*Operculodinium placitum* Drugg & Loeblich Jr., 1967	4	1,32	2	0,76
Operculodinium sp. 3 de Verteuil & Norris, 1996	-	-	2	0,76
Operculodinium sp. 1	3	0,99	-	-
Palaeocystodinium golzowense Alberti, 1961	2	0,66	8	3,03
Paucisphaeridium sp. indet.	-	-	1	0,38
Pentadinium laticinctum Gerlach, 1961 *subsp. laticinctum*	2	0,66	1	0,38
Polysphaeridium zoharyi (Rossignol, 1962)	9	2,98	9	3,41
Pyxidinopsis tuberculata Versteegh & Zevenboom, 1995	3	0,99	2	0,76
Pyxidinopsis sp.1	4	1,32	1	0,38
Reticulatosphaera actinocoronata (Benedek, 1972)	2	0,66	3	1,14
Spiniferites/Achomosphaera spp. (undetermined)	141	46,69	132	50,00
Sumatradinium druggii Lentin *et al* ., 1994	4	1,32	3	1,14
Sumatradinium hamulatum de Verteuil & Norris, 1996	-	-	1	0,38
Sumatradinium soucouyantiae de Verteuil & Norris, 1992	2	0,66	2	0,76
Systematophora placacantha (Cookson & Eisenack, 1955) subsp. *placacantha*	-	-	1	0,38
Tectatodinium pellitum Wall, 1967	2	0,66	1	0,38
Tectatodinium sp. 1	2	0,66	8	3,03
Tuberculodinium vancampoae (Rossignol, 1962)	1	0,33	1	0,38
Wetzeliella spp. indet. *	1	0,33	-	-
Total Dinoflagellata	303	100	264	100
Acritarcha				
Acritarch sp. 2 Head *et al.* 1989	-		1	
Cyclopsiella granosa / elliptica complex	8		11	
Cyclopsiella sp. cf. *C. granosa* (Matsuoka, 1983)	-		-	
Cyclopsiella ? laevigata Châteauneuf, 1988	2		-	
Cyclopsiella ? trematophora (Cookson & Eisenack, 1967)	-		1	
Cymatiosphaera baffinensis Head *et al* ., 1989	-		1	
Fromea sp. indet.	-		7	
Incertae sedis 1	-		-	
Michrystridium castaninum ? Valensi, 1953	1		-	
Nannobarbophora walldalei Head, 1996	2		1	
Paralecaniella indentata (Cookson & Eisenack, 1955)	2		10	
Platycystidia sp. indet.	1		3	
Total Acritarcha	16		35	
Chlorophyta				
Pediastrum boryanum	1		2	
Total palynomorphs	320		303	

Table 1. Distribution of marine palynomorphs in the Zonderschot Sands. Raw counts are given together with percentages for the dinoflagellate cysts. *: Probably reworked.

samples are the same as those studied by Hooyberghs (1980) for planktonic foraminifera. The fourth sample P5675 (collections of the Laboratory for Palaeontology, University Ghent) is from a temporary outcrop described by Huyghebaert & Nolf (1979) near Schaliehoeve (Fig. 1).

Palynological preparation followed standard maceration techniques. About a hundred grams of sediment was decalcified with 20 % HCl, followed by digestion for one or two hours in 40% HF at 70°C. The sediment was stirred thoroughly to suspend all fine particles and decanted. This step was repeated several times until all fine particles were recovered. The remaining sand fraction was discarded. The recovered fine fraction was again treated with 40% HF, followed by repeated hot baths (70-80°C) of 20% HCl. The samples were rinsed to neutrality between each step. No ultrasonic treatment or heavy liquid separation was applied. The residues were oxidised in 90% HNO_3 for 30 seconds and then neutralised by repeated washings in 10% KOH. The residues were sieved on a nylon screen with 20 µm mesh size, stained with Safranin-O and mounted with glycerine jelly. At least 250 complete individuals were counted for each sample. The rest of the slide was then searched for rare or exceptionally well preserved specimens. Photomicrographs were taken with interference contrast on a NIKON Optiphot microscope.

A diverse dinoflagellate cysts association was recovered (Table 1) and the preservation of the cysts is moderate to good. Its biostratigraphic interpretation is based on the dinoflagellate cyst biozonation of de Verteuil & Norris (1996). This zonation was established in the shallow marine deposits of the Salisbury Embayment (Maryland and Virginia) on the Atlantic margin of the U.S.A. It is based on 62 dinoflagellate cyst horizons which are indirectly calibrated to calcareous nannofossils and planktonic foraminifera data from offshore New Jersey, U.S.A. The resolution of this biozonation is relatively high, with an average zonal duration of 1.8 Ma. Plates 1 & 2 illustrate selected dinoflagellate cysts of stratigraphic importance. Dinoflagellate cyst nomenclature follows Williams *et al.* (1998). Reworking of pre-Neogene dinoflagellate cysts appears to be negligible: only a few specimens of *Wetzeliella* spp. indet. were encountered.

4. The Zonderschot dinoflagellate cysts

The associations from the outcrop Schaliehoeve and the type-locality are very similar and nearly indistinguishable, except perhaps for the relatively high numbers of *Apteodinium spiridoides* at the type-locality.

The Zonderschot Sands contain a dinoflagellate cyst association characteristic of the *Distatodinium paradoxum* Interval Zone DN4 of de Verteuil & Norris (1996), which is defined as the interval from the lowest occurrence (LO) of *Labyrinthodinium truncatum* to the highest occurrence (HO) of *Distatodinium paradoxum*. The eponymous species *Distatodinium paradoxum* and *L. truncatum* subsp. *modicum* are found in all four samples, while the autonym *L. truncatum* subsp. *truncatum* was not observed in the Zonderschot Sands. *L. truncatum* subsp. *modicum* slightly predates *L. truncatum* subsp. *truncatum* in the Salisbury Embayment (de Verteuil & Norris, 1996, de Verteuil, 1997) and in the continental slope and rise off New Jersey (de Verteuil, 1996). This phenomenon is also observed in the Antwerpen Sands of the type area (Louwye *et al.*, in press). However, both species often do not occur together in the same samples in the above mentioned areas, which might indicate that the occurrences are controlled by different environmental factors.

Apteodinium spiridoides, *Cousteaudinium aubryae* have a HO within the DN4 Zone in the Salisbury Embayment and occur intermittently in the Zonderschot Sands. The Middle Miocene key-species *Unipontedinium aquaeductum* from the *Batiacasphaera sphaerica* Interval Zone DN5 was not encountered in the Zonderschot Sands. Very low numbers of *Sumatradinium hamulatum*, a characteristic species with a HO in the *Cousteaudinium aubryae* Interval Zone DN3, were found. Its presence might be environmentally controlled or result from reworking; further research must re-assess its precise stratigraphic range.

At first glance, the dinoflagellate cysts association from the Zonderschot Sands is dominated by taxa associated with nearshore marine conditions, such as *Apteodinium* spp., *Dapsilidinium* spp., *Polysphaeridium* spp., *Systematophora* spp. and *Lingulodinium* spp. *Polysphaeridium zoharyi* is a species with a manifest preference for coastal to shallow marine environments. Head & Westphal (1999) found abundant *P. zoharyi* associated with high numbers of terrestrial palynomorphs in Upper Pliocene shallow marine deposits from the Great Bahamas banks. This species is well represented in all four samples and underscores the deposition of the Zonderschot Sands in a shallow marine environment at the very southern margin of the North Sea Basin. However, the prominent presence of *Nematosphaeropsis* and *Impagidinium* species, both with an oceanic/outer neritic affinity, in the shallow marine deposits is notable and at first sight contradictory. Dale (1996) stresses that the presence of even a few specimens of *Nematosphaeropsis* and *Impagidinium* is a reliable indication of the occurrence of oceanic waters. Such a low-diversity open marine or oceanic component in a marginal marine assemblage can typify the maximum flooding surface at the basin margin (Sturrock, 1996), which could be the case here. Low numbers of the freshwater chlorophyte *Pediastrum boryanum* in this case probably represents reworking.

5. Comparison with adjacent areas

The dinoflagellate cyst association from the Zonderschot Sands is comparable with the association found in the Antwerpen Sands in the outcrop "A.K. - Kievitstraat" and "B.R. - Rivierenhof", in Antwerp (Louwye &t *al.*, in press). Figure 4 gives the correlation with the assemblages found in samples A.K.50, A.K.64 and B.R. 2, which were placed in the lower part of the *Distatodinium paradoxum* Interval Zone DN4 of de Verteuil & Norris (1996). The dinoflagellate cysts associations from these intervals in the Antwerpen Sands compare well with those from the Zonderschot Sands. The only dissonant feature is the absence or rarity of *Apteodinium spiridoides* in samples B239, B238 and B237 with respect to the Antwerpen Sands associations, where this species is prominent in the DN4 Zone. However, *Apteodinium spiridoides* also becomes rare in the DN4 Zone in in the Salisbury Embayment (de Verteuil & Norris, 1996, de Verteuil, 1997) and in the continental slope and rise off New Jersey (de Verteuil, 1996).

6. Conclusions

The Zonderschots Sands are correlated with the uppermost Lower Miocene to lower Middle Miocene (uppermost Burdigalian to Langhian) *Distatodinium paradoxum* DN4 Zone of de Verteuil & Norris (1996). Since only *L. truncatum* subsp. *modicum* is present and *L. truncatum* subsp. *truncatum* was not found, a more precise correlation with the basal part of the DN4 Zone (uppermost Burdigalian - lowermost Langhian) could be possible. However, this more precise correlation should be approached with caution, since it is not possible to discriminate between the environmental factors controlling the occurrences of these species. Huyghebaert & Nolf (1979) consider the Zonderschot Sands to be a lateral equivalent of the Antwerpen Sands north of the Heist-op-den-Berg area. This correlation is corroborated by dinoflagellate cysts. Moreover, a precise correlation with a section in the lower part of the Antwerpen Sands in the Antwerp area is given. The shallow marine dinoflagellate cyst association from the Zonderschot Sands includes *Nematosphaeropsis* and *Impagidinium* cysts. These contemporaneous allochthonous cysts point to the presence of a of fully oceanic influence in the shallow marine depositional environment of the Zonderschot Sands, during a period of maximum landward extent of the marine realm.

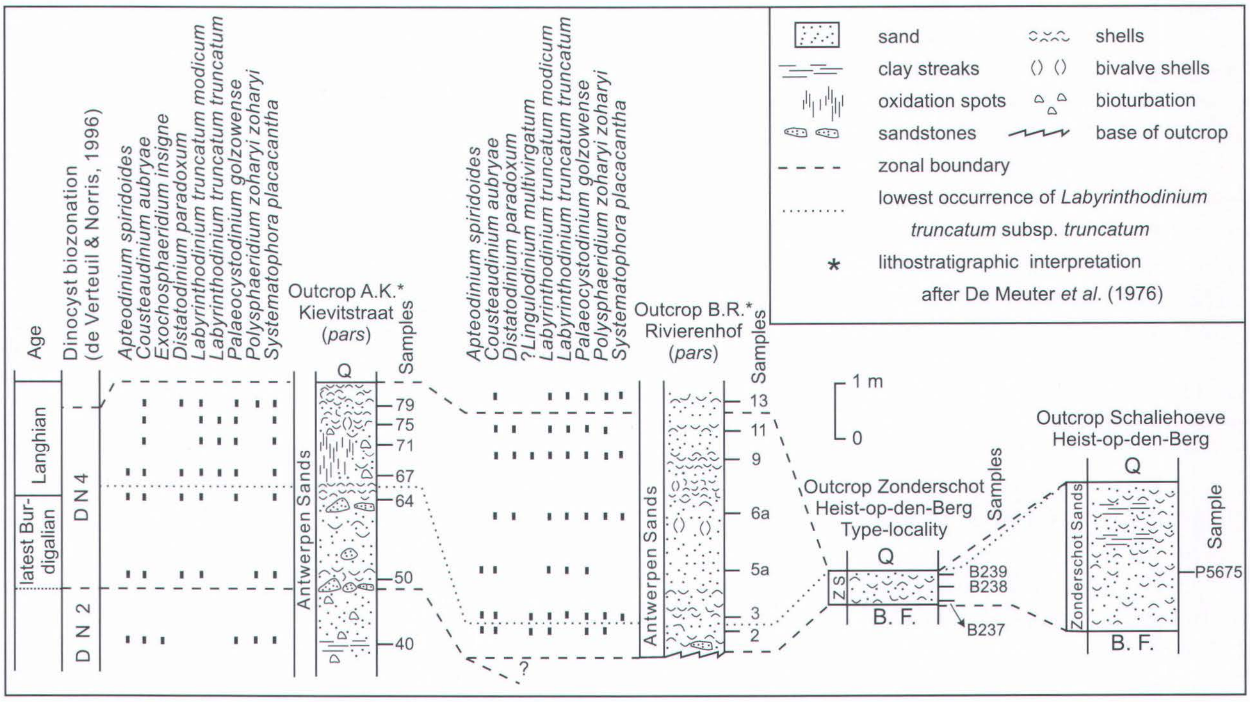

Figure 4. Biostratigraphical correlation between the Antwerpen Sands of the Berchem Formation in the Antwerp area and the Zonderschot Sands (not to scale horizontally). Q: Quaternary, B. F.: Boom Clay Formation, Z S: Zonderschot Sands.

7. Acknowledgements

K. Wouters (Royal Belgian Institute for Natural Sciences, Brussels) shared his ideas on the stratigraphy of the Zonderschot Sands and kindly made the samples from the type-area available. His kind co-operation is acknowledged. Discussions on Neogene stratigraphy with D. Nolf (Royal Belgian Institute for Natural Sciences, Brussels) are appreciated. Stimulating discussions with J. De Coninck (Laboratory for Palaeontology, Ghent University) and M. J. Head (University of Cambridge) on the morphology and taxonomy on some dinoflagellate cyst species are gratefully acknowledged. A. Gautier (Laboratory for Palaeontology, Ghent University) critically reviewed the manuscript and gave useful comments. M. Winsall (London, UK) kindly revised the English. I am grateful to S. Vancauwenberghe for help in processing the samples. This research was carried out in the framework of research project 01105098 of the Ghent University (promoters: J. De Coninck and J. Verniers).

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9. Appendix 1: remarks on selected dinoflagellate cysts

Cerebrocysta sp. cf. *C. satchelliae* de Verteuil & Norris, 1996 (Pl. 1, Figs. F-H)

The cyst diameter of 45 µm is relatively small compared to the type material from the Miocene of the Salisbury Embayment (Atlantic margin, U.S.A.) (de Verteuil & Norris, 1996; diameter: 47 (60) 76 µm). The ornamentation of the cyst body surface furthermore has a less granulate appearance, but a much denser network of irregular ridges with a height of ca. 1-2.5 µm. Archeopyle probably type 1P.

Filisphaera sp. cf. *F. microornata* Head *et al*., 1989 (Pl. 1, Figs. A-E)

This species is characterised by rather large septa with an average height of 4 to 6 µm. The reticulation formed by the septa is coarse, irregular and incomplete. The lumina are narrow, sinuous or straight and vary in size on each specimen. *F. microornata* Head *et al.* (1989) has septa with a height of ca. 1.5 to 2.3 µm together with a more complete and less irregular microreti-culation.

Lingulodinium multivirgatum de Verteuil & Norris, 1996 ? (Pl. 2, Figs. J-K)

The body surface of the cyst is faintly microgranular and covered with closely spaced, hollow and distally closed virgae. The virgae have a relatively broad base and taper rapidly. Length of virgae: 11 - 14 µm. The type material of *L. multivirgatum* de Verteuil & Norris (1996) differs in having a less dense ornamentation of the body surface with more slender virgae. The granulation of the cyst body surface is coarser.

Manuscript received November 5, 1999, accepted April 16, 2000.

PLATE 1

A - E. *Filisphaera* cf. *microornata* (Head *et al.* 1989). Sample B237-1/E57-4. Central body maximum diameter = 35 µm; height septa = 4-5 µm. A. Low focus on precingular archeopyle. B - D. Slightly differing high foci on septa. E. Optical section.

F - H. *Cerebrocysta* sp. cf. *C. satchelliae* de Verteuil & Norris, 1996. Sample P5675-1/X31-1. Cyst diameter including ridges = 46 µm. Apical - antapical orientation. F. Optical section, ambitus. G - H. Slightly differing high foci on ridges.

I - J. *Cerebrocysta poulsenii* de Verteuil & Norris, 1996. Sample P5675-1/D55-1. Total length excluding septa = 38 µm. I. Optical section and septa profile. J. High focus on archeopyle margin and septa.

K - L. *Labyrinthodinium truncatum* subsp. *modicum* de Verteuil & Norris, 1996. K. Sample B237-1/U41-4. Central body maximum diameter = 25 µm. Optical section, ambitus and virgae. L. Sample B237/V51-2. Central body maximum diameter = 26 µm. High focus on archeopyle.

M - N *Cordosphaeridium minimum sensu* Benedek & Sarjeant, 1981. Sample 237-1/O47-3. Central body diameter = 18 µm. M - N. Slightly differing optical sections, process morphology.

O. *Nematosphaeropsis labyrinthus* (Ostenfeld, 1903). Sample B237-1/V55-1. Width including trabeculae = 50 µm. O. Optical section, ambitus and trabeculae.

P. *Paralecaniella indentata* (Cookson & Eisenack, 1955). Sample B237-1/T41-1. Length without flange = 50 µm. Optical section.

Q. *Batiacasphaera minuta* (Matsuoka, 1983). Sample P5675-1/P29-2. Central body diameter = 28 µm. High focus on wall structure.

R. *Cyclopsiella granosa/elliptica* complex. Sample P5675-1/T58-4. Width of upper specimen with flange = 56 µm. Optical section.

S. Dinocyst sp. 7 Manum *et al.* (1989). Sample B237-1/P32-3. Width including luxuria = 34 µm. High focus on spongy luxuriae.

T. *Operculodinium*? *placitum* Drugg & Loeblich Jr., 1967. Sample P5675-1/D38-3. Central body length = 38 µm. High focus on microgranular luxuria and virgae.

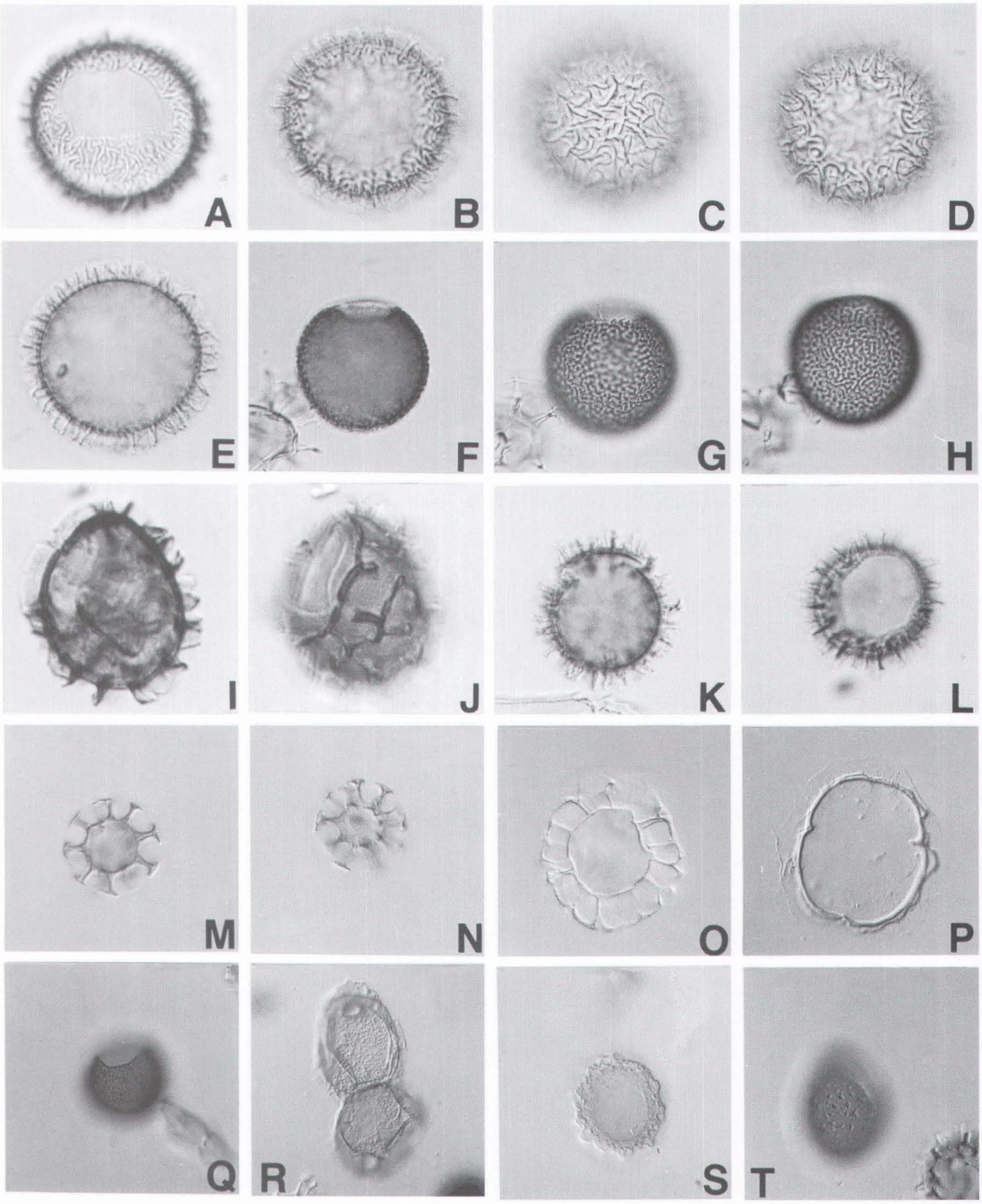
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PLATE 2

A - B. *Paleocystodinium golzowense* Alberti, 1961. Sample B237-1/O48-3. Cyst length = 162 μm; width = 38 μm. A. Low focus on epicyst and apical horn. B. High focus on hypocyst and antapical horn.

C - D. *Tectatodinium pellitum* Wall, 1967. Sample B238-1/J46-3. Diameter including luxuria = 38 μm. C. Optical section, spongy luxuriae. D. High focus on precingular archeopyle.

E. *Polysphaeridium zoharyi* (Rossignol, 1962). Sample P5675-2/F39-2. Central body maximum diameter = 42 μm. Optical section.

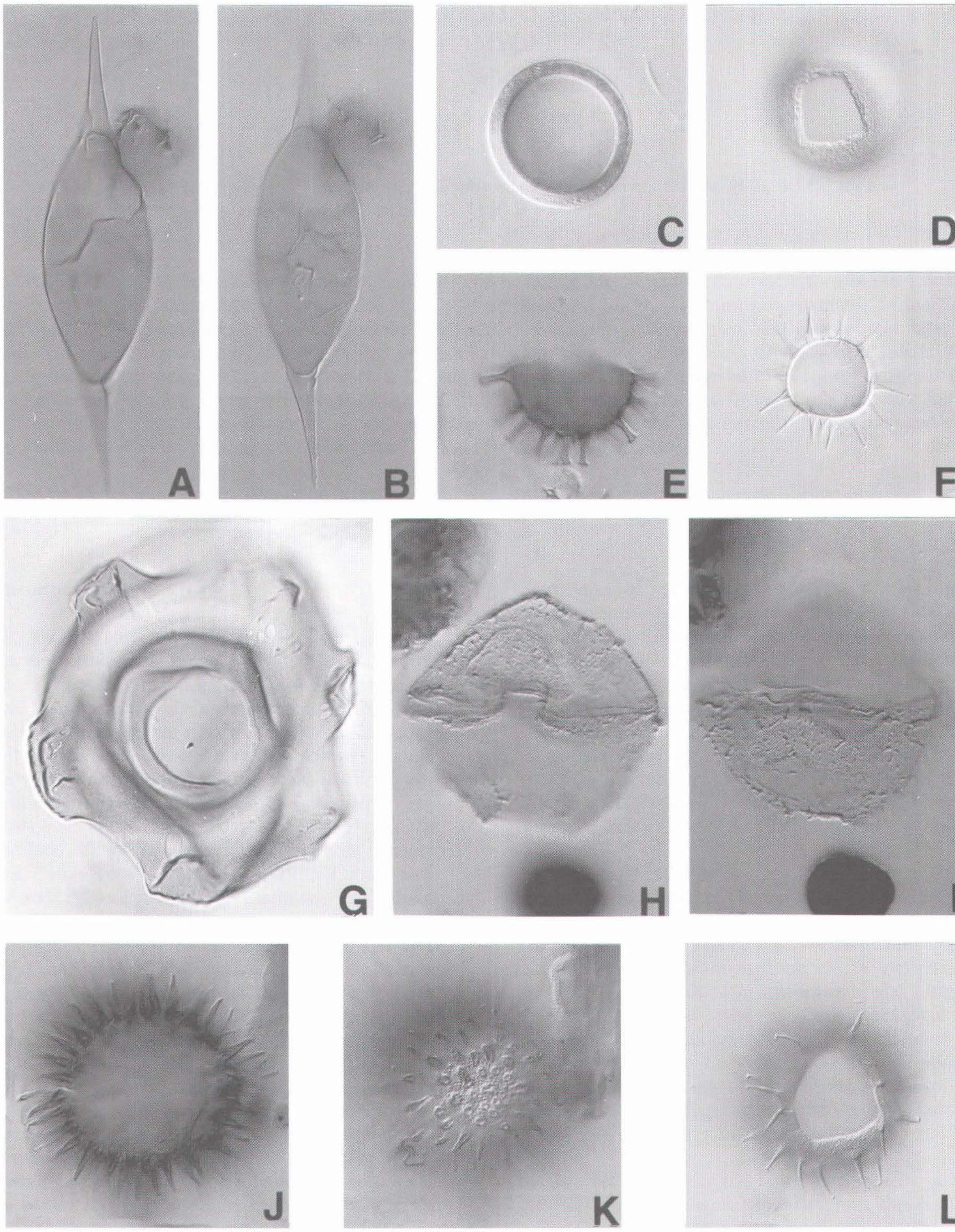
F. *Dapsilidinium pastielsii* (Davey & Williams, 1966). Sample 237-1/V55-2. Central body maximum diameter = 30 μm; length processes = 10-12 μm. Optical section.

G. *Cousteaudinium aubryae* de Verteuil & Norris, 1996. Sample P5675-2/N51-3. Diameter archeopyle = 32 μm. High focus on apical archeopyle.

H - I. *Sumatradinium hamulatum* de Verteuil & Norris, 1996. Sample B237-1/B39-3. Total length = 80 μm; width = 90 μm. H. Low focus on intercalary archeopyle and virgae alignment. I. High focus on hypocyst.

J - K. ?*Lingulodinium multivirgatum* de Verteuil & Norris, 1996. Sample P5675-1/Y37-1. Central body maximum width = 68 μm. J. Optical section, hollow virgae. K. High focus showing wall structure.

L. *Operculodinium centrocarpum* (Deflandre & Cookson, 1955) subsp. *centrocarpum*. Sample P5675-1/Y31-4. Diameter archeopyle = 28 μm. L. High focus on archeopyle.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